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I-22950

(7) DR.1283-1

UCID- 20497

SOFTWARE REQUIREMENTS DEFINITION SHIPPING CASK ANALYSIS SYSTEM (SCANS)

Gary L. Johnson
Richard Serbin

MASTER

July 21, 1985

Lawrence Livermore National Laboratory

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

UCID--20497

DE85 017880

ABSTRACT

The U. S. Nuclear Regulatory Commission (NRC) staff reviews the technical adequacy of applications for certification of designs of shipping casks for spent nuclear fuel. In order to confirm an acceptable design, the NRC staff may perform independent calculations.

The current NRC procedure for confirming cask design analyses is laborious and tedious. Most of the work is currently done by hand or through the use of a remote computer network. The time required to certify a cask can be long. The review process may vary somewhat with the engineer doing the reviewing. Similarly, the documentation on the results of the review can also vary with the reviewer.

To increase the efficiency of this certification process, LLNL was requested to design and write an integrated set of user-oriented, interactive computer programs for a personal microcomputer. The system is known as the NRC Shipping Cask Analysis System (SCANS). The computer codes and the software system supporting these codes are being developed and maintained for the NRC by LLNL.

The objective of this system is generally to lessen the time and effort needed to review an application. Additionally, an objective of the system is to assure standardized methods and documentation of the confirmatory analyses used in the review of these cask designs.

A software system should be designed based on NRC-defined requirements contained in a requirements document. The requirements document is a statement of a project's wants and needs as the users and implementers jointly understand them. The requirements document states the desired end products (i.e. WHAT's) of the project, not HOW the project provides them. This document describes the wants and needs for the SCANS system.

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1.0 INTRODUCTION

This is intended to be a working requirements document rather than final requirements declarations. The main purpose of this document is to stimulate and encourage thinking and discussion about the requirements for the proposed system. It is the reader's responsibility to question anything in this document and to suggest changes where needed.

A requirements document is a statement of a project's wants and needs as the users and implementers jointly understand them. There are many reasons for developing a formal requirements document. Establishing a requirements document facilitates user communication and user participation during system development. The document becomes a letter of understanding between the users and the implementers of what is really wanted. Success or failure of a software project often depends on the precision and completeness of this letter of understanding.

The requirements document should state the desired end products (i.e. WHAT's) of the project, not HOW the project provides them. The series of specification documents defines the "HOW's". Without formally defined requirements, it is difficult to show that a product works (i.e. that it satisfies the project's "WHAT's"). Each requirement should be written so that the performance of the product can be tested against this requirement at any phase of software development.

It is especially difficult to make reliable time and manpower estimates without a good requirements document and good specification documents. Finally, a good requirements document substantially shortens development time and ultimately decreases development costs!

1.1 Identification of the Problem

Containers for shipping the spent fuel elements of nuclear reactors must be designed to withstand various normal and accident conditions. To ensure adequate protection to the public, the Federal Government has specified requirements for the performance of these containers in Title 10 of the Code of Federal Regulations, Part 71, Subpart C (10 CFR 71)*. To obtain approval of a container design, licensees must submit an application demonstrating that the design meets these requirements. The NRC staff reviews the technical adequacy of these applications and issues Certificates of Compliance provided the application is acceptable.

Several methods may be used to evaluate a container design, i.e. full-scale testing; scale-model testing; and engineering analysis. Generally, most applicants choose to demonstrate the adequacy of their design through engineering analysis to verify the structural integrity of the cask against several failure modes including gross rupture, excessive deformation, fatigue, and buckling.

Two NRC Regulatory Guides, 7.6 and 7.8*, deal with these engineering analyses. Regulatory Guide 7.6 (RG 7.6) specifies the allowable stresses for normal and accident conditions. The allowable stress values are patterned after those for Class NB vessels in the ASME Code. The Guide, like the ASME Code, is based upon the maximum shear stress (Tresca) failure theory. Depending upon the type of load producing the stress and the location of the stress in the structure, stresses are classified as primary, secondary, peak, or total. Separate limits are specified for each category and for

*See Section 2.0 of this document for applicable documents combinations of categories (e.g., primary plus secondary). In addition, the Guide specifies the allowable stress limits for normal and accident conditions. Regulatory Guide 7.8 (RG 7.8) specifies the individual loads that should be considered. Because more than one type of load may be applied simultaneously to the package, RG 7.8 also specifies the load combinations that should be addressed in the application.

Regulatory Guide 7.9 (RG 7.9) was compiled as an aid in the preparation of applications for approval of packaging to be used for the shipment of type B, large quantity, and fissile radioactive material. It sets forth a desired format and content for the cask certification applications. As such it provides a natural checklist for the initial review of incoming applications by the NRC.

To verify the requirements set forth in the Code and Regulatory Guides for applications using analyses, licensees may select various design methods. These methods vary from simple static analyses, to closed-form solutions with simplifying assumptions, and possibly to very complex 3-dimensional finite element analyses. Whatever method is used, a set of assumptions is assigned. Due to non-uniform methods used by the licensee in these design analyses, the assumptions made in one application vary greatly from those made in another. *In order to confirm an acceptable design, the NRC staff* may perform independent confirmatory calculations.

The current NRC procedure for confirming a cask design is laborious and tedious. Most of the work is done by hand or through the use of a remote computer network. The time required to certify a cask is longer than desired. The review process may vary somewhat with the engineer doing the reviewing. Similarly, the documentation on the results of the review can also vary with the reviewer.

In order to increase the efficiency of the process of certifying shipping cask designs, LLNL was requested to develop an integrated set of user-oriented, interactive computer programs. The system shall be known as the *NRC Shipping Cask Analysis System (SCANS). The computer codes and the* software system supporting these codes will be developed and maintained for the NRC by LLNL.

1.2 Functional Summary

The system shall consist of a series of computer programs to analytically determine the response of the modeled shipping cask to various thermal and mechanical loads. The response to the thermal loads is defined in terms of the maximum temperature and the temperature distributions. The response the mechanical loads is evaluated in terms of stresses. The classifications of stresses used in this evaluation are: general primary membrane stress, local primary membrane stress, primary bending stress, secondary stress, and peak stress. Global kinetic response of the cask will largely utilize lumped-parameter dynamic models. Recovery of local stresses is usually accomplished by using static methods on the cross section of the cask with these global forces applied.

The software framework which ties all these analytical computer codes into an integrated system provides

A. A common input editor and database. Each cask design review application would have its own input database.

B. A common material properties editor and database.

C. A common cask geometry editor, mesh generator, and database. Each cask design review application would have its own geometry database.

D. An editor and an archival database containing the results of the thermal and structural analyses. Each cask design review application would have its own results database.

E. A special computer program to determine the expected stress levels due to various load combinations per RG 7.8. These load combination stresses would be based on the individual load stresses calculated by the various analytical computer codes. The combined-load stresses would then be compared with the acceptable levels defined by the NRC Regulatory Guides 7.6 and 7.8

F. Certain post-processors to provide the results in printed and graphical formats.

1.3 Basic Assumptions

A. Access to this Analysis system shall be available through a computer in the user's office.

B. All the computer code modules and support software will be contained on a single computer, except for those mainframe-based codes which are to be used when the most complex analyses are needed.

C. A single software framework will be developed which integrates and accesses all analytical code modules, pre-/post-processors, and databases.

D. This software system will provide a basis for the NRC to establish a standardized procedure for confirmatory review of shipping cask designs supported by Analysis.

E. This software system will also provide a basis for the NRC to establish a standardized procedure for documenting the results of this review and for archiving the individual analyses results used in the review.

F. The system shall be user-friendly, i.e., it will require

* a computer system that is transparent to the user,
* a self-help information package,
* easy recovery from user input errors or numerical solution faults,
* automatic generation of simplified models of the cask by established rules, parameters, et cetera, hardwired in individual computer codes.
* default values for input data (based on 10 CFR 71, RG 7.6 and 7.8) built into the system.

2.0 APPLICABLE DOCUMENTS DEFINING APPLICATION REVIEW NEEDS

A. Code of Federal Regulations, Part 71 of Title 10, Chapter 1, Office of the Federal Registrar, Washington, D.C., March 2, 1979 (Revised September 1983).

B. Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6, International Atomic Energy Agency, Vienna, 1973 rev. ed.

C. Code of Federal Regulations, Parts 170-189 of Title 49, Office of the Federal Registrar, Washington, D.C., January 1, 1983.

D. U. S. Nuclear Regulatory Commission, Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Revision 1, March 1978.

E. U. S. Nuclear Regulatory Commission, Regulatory Guide 7.8, "Load Combinations for the Structural Analysis of Shipping Casks," May 1977.

F. U. S. Nuclear Regulatory Commission, Regulatory Guide 7.9, "Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material," Revision 1, January 1980.

G. 1) ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsections NA and NB, Appendices and Class 1 Components and 2) Criteria of the ASME Boiler and Pressure Vessel Code for Design by Analysis, Sections III and VIII, Division 2, American Society of Mechanical Engineers, 1983.

3.0 FUNCTIONAL REQUIREMENTS

3.1 Objective of the System

Generally, the objective of the system is to lessen the time and effort needed to review an application for certification of a spent fuel shipping cask. The desire of NRC is to reach this objective by automating a review procedure on a personal micro-computer. Additionally, an objective of the system is to assure standardized methods and documentation of the confirmatory analyses used in the review of these cask designs. Specifically, the objective of the system is to provide an integrated series of computer codes for calculating the response of a shipping cask to the various thermal and mechanical loads defined by 10 CFR 71 and RG 7.8. The system would then compare these responses to levels allowed by RG 7.6 and document these results. Also the system would check if the cask certification application contained all the information defined by RG 7.9. A final objective of this work is to provide both a means whereby this Requirements Document can be updated as new requirements appear, and a means whereby the specification documents can be altered as changes to the system are needed.

3.2 Input Information Requirements

The input information shall be divided into two categories: 1) data stored on computer magnetic storage media such as databases, and 2) data input from the keyboard. Most of the specific input data required by each code shall be specified during the system specification development. Input information used by a variety of computer code modules shall be stored on the computer in the Input Database. Ease of input will be provided interactively by the system Input

Editor code through

A. clear, descriptive informational input requests.

B. internal input data checks for reasonableness, validity, and consistency.

C. built-in default values for most initial and boundary conditions.

D. the capability to review and modify the entire input for a given code.

For input data not accepted, the system code will provide an instructive message explaining the error and will allow the corrected values to be re-entered. The ability to easily review and modify, through full-screen editing, any existing input data file shall be available.

All data used as input for a given Analysis shall be stored with the results of that Analysis in the archival Analyses / Load Combination Results database. Thus, the user can rerun a previous Analysis by simply recalling the original input data from the archival database, modifying it if desired, and proceeding to the appropriate Analysis code.

Each input data set will include the time and date of the Analysis, the user's name, a descriptive title, a cask design docket number, the Analysis code I.D. (including version number), the input cask description, initial and boundary conditions, and Analysis control parameters.

3.3 Processing Requirements

3.3.1 Confirmatory Analysis Computer Calculation Requirements

The design Analysis conditions to be reviewed by the NRC are given in Table I and Table II. The maximum temperatures allowable are given in Table III. Calculated temperatures are used for comparison against regulatory allowables and as input to the structural codes for determining the correct values of the material properties and/or thermally-induced stresses. The calculated thermally-induced stresses and all other predicted stresses are passed to the stress-due-to-load-combination computer code for summation prior to comparison with the allowable levels set by the Regulatory Guides.

TABLE I

Load Types For Shipping Casks

I. Normal Conditions (to be considered as independent occurrences)

1. Thermal Loads
   a. Initial thermal conditions
   b. Cold environment = $-40^{\circ}F$

2. Pressure Difference Loads
   a. Internal pressure due to thermal heating of gas
   b. Minimum External Pressure = 0.5 atm

3. Shock Loads, Vibration and Cyclic Fatigue Evaluations

4. Free drop = 1 foot (Impact Loads)
   a. end [longitudinal stresses]
   b. side [longitudinal stresses]
   c. corner under center of gravity [longitudinal stresses]
   d. oblique [longitudinal stresses]
   e. secondary (slapdown) [longitudinal stresses]
   f. lateral pressure of Pb [circumferential stresses]
   g. force vs. deflection of Impact Limiters

II. Accident Conditions (to be considered as sequential occurrences)

1. Free drop = 30 foot (Impact Loads)
   a. end [longitudinal stresses]
   b. side [longitudinal stresses]
   c. corner under center of gravity [longitudinal stresses]
   d. oblique [longitudinal stresses]
   e. secondary (slapdown) [longitudinal stresses]
   f. lateral pressure of Pb [circumferential stresses]

2. Free drop = 40 inches onto rounded end of 6" dia. bar (Puncture Loads)
   a. local stresses
   b. overall response

3. Fire = 30 min. @ $1475^{\circ}F$ thermal radiation source (Thermal and Pressure Difference Loads)
   a. Temperature limits
   b. Thermal stresses
   c. Pressure stresses

III. Buckling
IV. Bolted closures
V. Fatigue Failure
VI. Load Combination and Temperature Limits
VII. Shock Loads
VIII. Lifting/Tie-Down Loads (lug design)

TABLE II-A.

Summary of Load Combinations for Normal and Hypothetical Accident Conditions of Transport

Applicable Initial Condition

Normal or Accident Condition	Ambient Temperature		Insolation		Decay Heat		Max. Internal Pressure**	Max. Weight of Contents
	100^oF	-20^oF	Max.*	0	Max.	0		
NORMAL CONDITIONS								
Cold Environment- -40^oF ambient			X		X		X	
temperature			X			X	X	
Minimum Ext. Pressure -	X		X		X		X	
0.25 atm		X		X	X		X	
Vibration & Shock# - Normally	X		X		X		X	
incident to the mode of		X		X	X		X	
transport		X		X		X	X	
Free	X		X		X		X	X
drop -		X		X	X		X	X
1 foot drop		X		X		X	X	X

* See Table 1 of Regulatory Guide 7.8.

** See Regulatory Guide 7.8, Section C.1.c and C.1.d, for a discussion of sources of internal pressure.

\# See Regulatory Guide 7.8, Section C.2.d for a discussion of "Vibration and fatigue."

TABLE II-B.

Summary of Load Combinations for Normal and Hypothetical Accident Conditions of Transport

Applicable Initial Condition

Normal or Accident Condition	Ambient Temperature		Insolation		Decay Heat		Max. Internal Pressure**	Max. Weight of Contents
	$100^{\circ}F$	$-20^{\circ}F$	Max.*	0	Max.	0		
ACCIDENT CONDITIONS								
Free	X		X		X		X	X
drop -		X		X	X		X	X
30 foot drop		X		X		X	X	X
Puncture -	X		X		X		X	X
40 in. drop		X		X	X		X	X
on 6 in. bar		X		X		X	X	X
Thermal## -								
Fire Accident	X		X		X		X	

* See Table 1 of Regulatory Guide 7.8.

** See Regulatory Guide 7.8, Section C.1.c and C.1.d, for a discussion of sources of internal pressure.

\## Evaluations should be made 30 minutes after start of fire and at post-fire steady-state conditions.

TABLE III.

MAXIMUM ALLOWABLE TEMPERATURE REQUIREMENTS

Material	Maximum Temperature (^{o}F)
Low-alloy Steel	700
Martensitic Stainless Steel	700
Carbon Steel	700
Austenitic Stainless Steel	800
Nickel-Chromium-Iron	800

3.3.2 Cask Geometry Editing, Mesh Generation, and Display

To assist the user in defining the cask geometry, built-in descriptions of the common generic shipping cask designs shall allow for input of the characteristic dimensions and the appropriate materials I.D.'s Cask materials shall be identified by a characteristic name which is referenced in the material properties database. For "non-standard" geometries, the user shall be able to create the appropriate representative geometry and materials. This system shall include a mesh generator for use with the 2-D and 1-D finite element codes.

For lumped-parameter analyses, the cask geometry shall be modeled in terms of representative beams or other simplified sections using the accepted rules needed by the particular Analysis. These modeling rules shall be built into each code. Based on accepted rules of modeling, specifying composite beam sections representing the actual structure shall also be automated. These rules of modeling are to be defined by the system specifications or by the developers of analytical codes.

3.3.3 Material Property Database Review and Modification

The properties of the most common materials used in these shipping casks are to be provided by the system developers in the form of a Material Properties Database. Using a unique material identification name, the properties necessary for any given Analysis will be extracted automatically by the individual module from the appropriate section within the Material Property Database. The code developer will access the appropriate material property by routing the input request to the relative location defined by the system specifications. The database material properties shall be developed from those documented in the ASME Boiler Pressure Vessel code or from the appropriate ASTM databases.

The user shall be inhibited from modifying these properties. Thus, all review analyses shall be based on the same set of material properties. The properties of additional materials, under other unique identification names, can be added by the user to his copy of the Material Properties Database. Use of such "added" materials shall be highlighted in the results.

3.3.4 Load Combinations and Regulatory Guide Comparisons

The results of the structural calculations, in terms of the stress components along the coordinate axes, are combined according to Regulatory Guide 7.8. Principal stresses due to the combined-stress components are then calculated. The stress intensities due to load combinations are calculated from the principal stresses. Using Regulatory Guide 7.6, comparisons of stress intensity shall be made to test compliance with 10 CFR 71 and the Regulatory Guides.

The user shall also have the option of selecting any load combination from the results of individual load cases and determining the resultant stress intensity. A generalized schematic of the projected software system is shown in Figure 1.

3.4 Output Information Requirements

Output shall be available to the user on both the computer terminal screen (temporary copy) and a local printer (hard copy). The output device shall be interactively selectable by the user or as part of an input file. The level of detail of the output information shall also be controllable by the user, e.g., maximum and minimums only, all nodal values for the worst case conditions, or time history nodal values. Schematic or graphic output as well as printed output shall be available to the user. For comparison purposes, the user shall be able to create plots where the results of various calculations are plotted on the same axes set. All output shall include source of calculations, title, date of creation, user name, input data, LLNL consultant, et cetera.

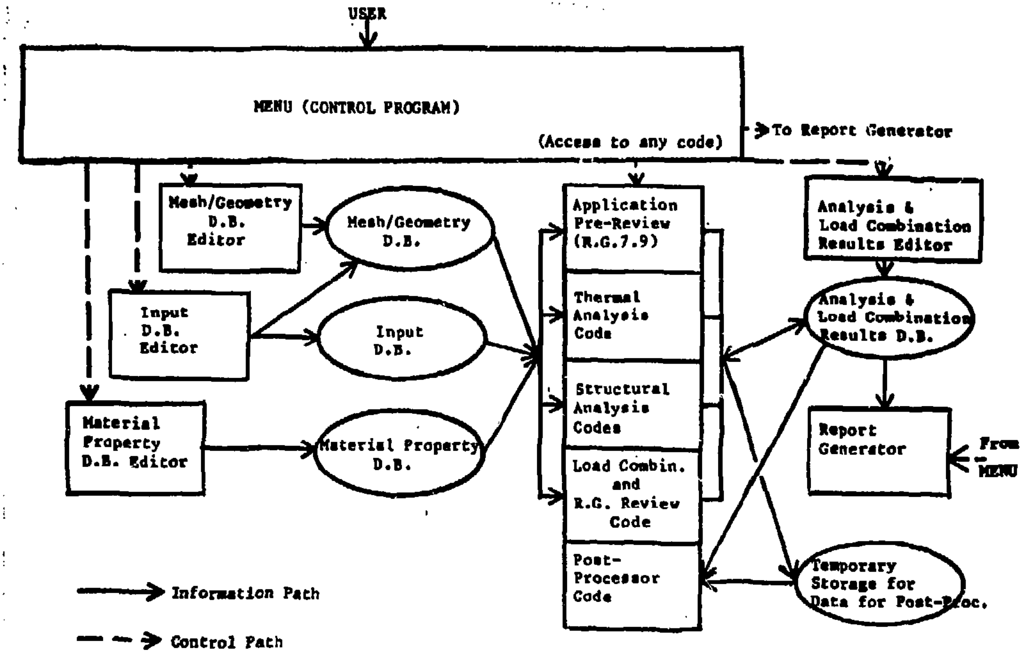

Figure 1. Schematic of the Proposed System based on the Requirements Document

3.4.1 Input Data Description

A. Cask I.D. name and docket number.

B. Input information for all code modules and cases, including code module I.D. and version number, Case I.D. and the input cask description, initial and boundary conditions, and Analysis control parameters.

C. System description, including all code module and database I.D.s and version numbers.

D. Input Database contents and layout.

3.4.2 Cask Geometry Description

A. Cask geometry I.D. name.

B. Synopsis of the cask geometry characteristic dimensions, materials, and cask contents weights.

C. Nodal coordinates and element descriptions for all the cask models.

D. Schematic representations of the cask models, as well as any desired sections.

E. Schematic representations and nodal/ element numbering of the cask meshes used in the analyses.

F. Cask Geometry Database contents and layout.

3.4.3 Material Property Description

A. Material I.D. name.

B. Any material property of a material available from Material Property Database to include:

1) Material property vs. material temperature, strain rate (e.g. for lead), corrosion, material orientation (i.e. orthotropic properties).
2) Stress vs. strain (when necessary for lead plastic strain).
3) Fatigue curves.

C. Printed tables or plotted curves

D. Material Properties Database contents and layout.

3.4.4 Individual Analysis Results Description
(from a temporary file for post-processing)

A. Detailed results available on a code by code basis to include:
1) Parameter vs. location, node, element.
2) Parameter time histories vs. location, node, element.
3) Parameter profiles along a given line or isoparametric profiles for any cask part or material.
4) Specific single parameter.

B. Printed tables or plotted curves.

3.4.5 Load Combinations & Regulatory Guide Comparisons Descriptions

A. Identify conditions and locations which fail to satisfy Regulatory Guide, include any contributions to load combination results.

B. Review of current status of Analyses / Load Combinations Results Database.

C. Format results of all comparisons for use in documenting in the compliance review documents.

3.4.6 Application Review Checklist and Report Generation

A. Checklist for initial application review.

B. Report form generator.

C. Local word processor.

D. Audit trail generator.

3.5 Database Requirements

Each database shall have a standardized filename and a standardized format for access by all programs. Information stored in each database shall be available for review on the terminal screen or as output from a local printer. The database review shall be controllable interactively by the user. All databases will include source or reference document for all data, descriptive title, creation date of current version of the database and date of the last change, LLNL consultant, et cetera.

3.5.1 Input Database Information (for all codes and cases run)

A. Unique cask I.D. name and docket number.

B. Code I.D. and version number Case I.D. and title Analysis and output control parameters

C. Input cask description, including material I.D.s

D. Initial conditions

E. Boundary conditions

F. Geometry database I.D. name and version number.

G. Material properties database I.D. name and version number.

H. Input Database table of contents and information layout.

3.5.2 Cask Geometry Database Information

A. Unique cask design identification name and docket number.

B. Characteristic cask dimensions and materials.

C. Characteristic dimensions of beam, et cetera, used in lumped-parameter models of the cask along with the codes using such models.

D. Nodal coordinates and element descriptions of the geometry meshes used in the finite element analyses along with the codes using such models.

E. Cask Geometry Database table of contents and information layout.

3.5.3 Material Property Database Information

A. Unique material identification name.

B. Density (at reference temperature)
Coefficient of thermal expansion vs. Temperature

C. Thermal properties /
Enthalpy of phase change (fusion and vaporization)
Thermal conductivity vs. Temperature
Specific heat capacity vs. Temperature
Heat generation rate vs. Temperature
Surface thermal radiative emissivity vs. Temperature

D. Structural properties / Tensile yield strength vs. Temperature
Ultimate strength vs. Temperature
Modulus of Elasticity vs. Te ,. 'ature
Poisson's ratio Stress intensity limit vs. Temperature
and type of stress
Fatigue curve (peak stress vs. number of cycles)

E. Cask Geometry Database table of contents and information layout.

F. Units for the material properties are set by the ASME code and ASTM databases.*

3.5.4 <u>Analyses / Load Combinations Results Database Information</u>

A. Nodal temperatures for all cases.

B. Nodal stresses for all steady state cases.

C. Maximum/minimum stresses (and associated locations and times) for all transient cases.

D. Final conditions (stresses, geometries, velocities, et cetera) for all transient cases.

E. Results of comparisons with Regulatory Guides.

*This requirement imposes corresponding units to variables of the analytic and post-processor codes.

3.6 System Capacities

The required software system capacities control the required RAM integral to the computer and the magnetic storage attached to the computer (hardware system capacities).

3.6.1 Software

A. Analytical Codes

1) Computer programs (largest individual code and total system of codes)

2) Data storage arrays (largest total required by any code and temporary arrays used for post- processing)

B. Support Software

1) Computer programs (largest individual code and total system of codes)

2) Input Database (maximum per cask design)

3) Cask Geometry Database (maximum per cask design)

4) Material Properties Database (standard materials plus space for four extra)

3) Analyses / Load Combination Results Database (maximum per cask design)

3.6.2 Hardware

A. Solid-state computer random access memory (RAM).
Install maximum addressable storage for computer (e.g., IBM PC=640 kB & IBM AT=3 MB)

B. High speed, fixed media, magnetic memory (Hard Disk).
1 Hard disk for system programs/system databases storage (e.g., IBM PC Expansion Unit hard disk=10 MB, IBM AT=20 MB).
1 Hard disk for temporary storage of intermediate data used by multiple computer programs, for case results to be

archived, and for data to be used by post-processing codes (e.g., an additional 10 MB Unit can be added to the IBM PC Expansion Unit).

C. High-speed, removable media, magnetic memory (Cartridge Hard Disk).
For use in system software installation, system and data backup, archival storage of the cask design related databases, and reports documenting the review results (e.g., Univation 10 MB cartridge hard disk can be installed in the IBM PC Expansion Unit. Same unit can be used in place of the second fixed disk mentioned above.).

4.0 OPERATIONAL REQUIREMENTS

4.1 Analysis Computer Codes

Input can be provided interactively to the Input Database from the keyboard through previously generated input files in the Input Database. Material properties and cask geometry shall be accessed by all codes from their appropriate on-line databases. To allow for easy user review, an individual Analysis should take no longer than 4 hours to complete on the computer. Numerical failures (e.g., non-convergence of the calculation, division by zero, logs of a negative number, et cetera) during any Analysis shall return control to the user with an appropriate explanation of the failure. Output information from the analytical codes shall be in terms of the stress components and temperatures. Storage of the input data and analyses results from a temporary buffer in RAM to the magnetic disk shall be automatic. The codes will be provided with a capability to interrupt the calculations for a review of the intermediate results. Restarting the calculations will involve just hitting a "CONTINUATION" key.

4.2 Support Software

The support software, or software framework, ties the series of analytical codes into an integrated system. It provides for common sources of input data and common sinks of output data. It provides a common, user-friendly control for accessing any of the codes in the system, e.g. menu. It provides a common post-processor for reviewing the results of any Analysis. Also it provides interfaces with the systems telecommunications and document generator packages.

The software framework for the analytical codes shall be designed with all expected software units identified. Installation of a newly developed software unit need only require storage on the system disk under its previously established filename. All file creation for internally generated databases will be initiated by the support software. All file creation for temporary data files for post-processing will be initiated by the generating code. The support software will provide the capability to use a command file to provide batch use of the system codes.

4.3 Software Documentation

All software shall be documented according to formats contained in the system specifications. Rules for modifying requirement, specification, or design documents will be included within the respective documents. All modeling rules, required input data, default input parameters, input data checking guides, equations, software switches, output data, et cetera, shall be included in this documentation. The list of documentation shall include:

A. System Requirements Document

B. System Specifications Document

C. Code (or Database) Specifications Documents

D. System Design Document

E. Database Editor/Analytic Code/Post-processor Design Documents

F. Database Editor/Analytic Code/Post-processor User's Manuals

G. Database Design Documents

H. Database User's Manuals

I. System Code Listing/Parameter Name Cross Reference

J. Database Editor/Analytic Code/Post-processor Listing/Parameter Name Cross Reference.

4.4 Software Maintenance

LLNL will provide a copy of the software to the Argonne National Lab Computer Software Bank. Software will be maintained by LLNL with additions and corrections shipped to NRC by means of either a telecommunications link or a hard disk cartridge through the mail. Problem cases or malfunctioning codes can also be transmitted by modem to the LLNL consultants for review and, if necessary, correction. The hardware and each software module will have an assigned consultant at LLNL who may be called on for assistance. The name and phone number of the consultant will be shown in the user's manual, on the output, and also in the Help Package.

5.0 SYSTEM PERFORMANCE

5.1 System Verification

Where possible, each analytic code shall be checked against closed form solutions (VERIFICATION), standard calculational tools and previous analyses (BENCHMARKING), and experimental data (VALIDATION). The results from a micro-computer-based code shall be checked for precision and accuracy against its corresponding version operating on the mainframe computer.

The contents of each system database shall be hand-checked against the corresponding database specification document and design document. Graphic displays from all post-processors shall be checked against corresponding printed data originating from the Analysis codes. All error checks and data checks will be tested for response and soft-failure results. All automatic control and data routing sequences provided by the software system will be checked against the system specifications.

5.2 Software switches

Software switches are provided for interaction with a code during operation. In analytical codes, they allow the user to stop the execution, to check the level of completion of the Analysis, to check the values of certain parameters (e.g., nodal temperatures or stresses, convergence criteria, time), or to alter certain control parameters affecting the step size or convergence criteria. In other software, they can stop data post-processing, allow for re-entry of input control parameters, and restart execution after a stop. These software switches are toggled from the keyboard by keying in certain characters.

6.0 RELIABILITY

6.1 Statement of system reliability needs

Only acceptable code use sequences will be allowed by the system (e.g., structural codes run after appropriate thermal data is generated and stored in the archival files). Use of non-standard codes for input to the load combinations calculations will not be permitted. Failures under operation in the Batch Mode (i.e. automated sequential code execution) shall cause a halt in the sequence of operations until it is cleared by a user.

For long execution time calculations, storage of intermediate Analysis results to the temporary storage hard disk shall occur automatically during completion of the Analysis. The system shall allow for restart of these calculations using the last intermediate data dump as the initial condition. Archival data shall also be stored automatically on this same disk until it has been stored on the archival cartridge and its backup data disk. Information backup of the system disk shall be required before initiating any use of a newly created or changed system.

6.2 Statement of allowable failures

No requirements set as yet.

7.0 INTERFACE REQUIREMENTS

7.1 To the Outside World

A. The system shall contain an automatic call/answer modem for connection with a mainframe computer as well as with other SCANS users. Also, it shall provide software to use this modem both interactively for work time communication and in batch mode using a stored command file for automatic data transmission off-hours (i.e. as a terminal emulator and/or for electronic mail).

B. An RJET (remote job entry terminal) shall be accessible to the micro-computer for use in printing out files from the mainframe analyses, e.g., normally hooked by high-speed telephone line to the mainframe computer.

C. A consultant shall be available at LLNL for each piece of software in the system for problem solving and incorporating system improvements.

9.0 GLOSSARY OF TERMS

A. BUFFER: An area of storage which is used to compensate for a difference in rate of flow of data, or time of occurrence of events, when transferring data from one device to another. Usually refers to an area reserved for input/output operations, into which data is read or from which data is written.

B. DATABASE: A file for storing data in a previously defined format for access by any code.

C. FILE: A set of related records treated as a unit.

D. HARD COPY: A printed copy of machine output in a visually readable form.

E. HARD DISK: A circular, high speed, high capacity, magnetic disk for storing data (usually composed of multiple rigid elements).

F. HARDWARE: The mechanical and electrical portion of the computer system.

G. MATRIX PRINTER: A printer which creates characters or figures by means of a matrix of dots rather than using preformed characters as are found on a typewriter.

H. MENU: A display on the monitor screen which allows the user several choices of action by keying in the appropriate code.

I. ON-LINE: The portion of the system available on the user's computer.

J. OPERATING SYSTEM: Software that controls the execution of programs; often used to refer to DOS.

K. POST-PROCESSOR: Software which allows the user to review the results of previous completed calculations.

L. RAM (Random Access Memory): Storage in which you can read and write to any desired location. Sometimes called direct access memory.

M. RECORD: A collection of related information, treated as a unit. For example, the title of a computer model Analysis or the description of a mesh element may be treated as a record.

N. ROM (Read-only Memory): Storage where access to the data is limited to read only, i.e. no modification.

O. SCREEN (MONITOR): An electronic display device for temporarily showing information generated by the computer.

P. SOFT-FAILURE: A condition during code execution where a numerical or software control failure is handled with a controlled termination of the computer code to a state recoverable by the user.

Q. SOFTWARE: The language and data portion of a computer system.

R. STANDARDIZED FILENAME: All files are identified by the computer system by their filename. A standardized name is set up under a series of fixed rules, e.g. all database file names start with "DB."

S. TERMINAL: A device, usually equipped with a keyboard and display, capable of sending and receiving information.

T. UPDATE: To modify, usually a master file, with current information.

U. WORD PROCESSOR: A computer program that allows the user to treat a computer as a semi-intelligent document generator.

9.0 REFERENCE DOCUMENTS ON SYSTEM PROPOSALS AND IMPLEMENTATION:

A. C. K. Chou, Proposal on "Development of Methods of Analysis for Radioactive Material Shipping Containers," LLNL, Nuclear Systems Safety Program, s183-145, June 10, 1983.

B. NRC FIN A0291-3 Task 7, "Methods for Impact Analysis of Radioactive Material Shipping Containers".

C. NRC FIN A0374 Project 3, "Method of Analysis for Shipping Containers Design".

SCANS

APPENDIX A

User Survey Comments

REQUIREMENTS DOCUMENT INTERVIEW QUESTION LIST

1. To aid in weighting your interview responses with others, indicate the length of time you have been reviewing shipping casks designs.

   /__/ 0-1 year   /__/ 1-3 years   /__/ more than 3 years

   a. What areas of the review process are you primarily involved in? e.g., thermal, structural, load combination?

   b. We understand that casks presented for review usually fall within a set of five generic designs. Based on your experience, do you find this to be the case?

   . In your experience are there certain conditions that cause critical stresses in a particular type of cask design?

   d. What is your procedure for reviewing shipping cask designs? Do you have suggestions for a standard procedure for these reviews? (Document each as closely as possible in detail.)

   e. What specific methods or computer codes do you use in these confirmatory analyses?

   f. Is it necessary to use them all for every type of cask design? (e.g., fire condition thermal, thermal stress, oblique impact, buckling)

   g. What is your procedure for documenting these confirmatory analyses? Do you have suggestions for a standard procedure for documenting these confirmatory analyses?

h. What format do you use for reporting the results of your review? Do you have suggestions for a standard report format?

i. How do you provide for an audit trail of the information used as input, analytical method, results, et cetera? We would like to provide a standard procedure for defining the audit trail for the review. Do you have suggestions for a standard procedure for this effort?

j. What sources do you use for input information for your analyses?

k. Do you have a set of reference designs for comparison with a new design?

l. Do you use other groups or subcontractors to assist you with your more difficult calculations?

m. About how long does it take to complete the review of a shipping cask?

n. Do you know of any plans for change or expansion in the current procedures for reviewing shipping cask designs, i.e., near-term / long-term?

o Do you have suggestions for improving the current way of doing things?

2. What experience do you have with microcomputers?
   a. On what machines and with what software?
   b. Do you have access to a microcomputer?

3. What experience do you have with main frame computers?
   a. On what machines and with what software?
   b. Do you have access to a main frame computer?

4. How would a coordinated, micro-computer-based system containing codes for calculations necessary to confirm a cask design assist you in your work?

5. What form do you see as desirable for this system's
   a. program access, e.g., menu-driven, code name, et cetera?
   b. program input, e.g., interactive question/answer, off-line input files?
   c. program output, e.g., printed, graphic, screen, parameters?
   d. comparison with allowable ranges of temperature and stress?
   e. access to changes or updates in the data bases or computer codes?
   f. telecommunication with code developers or a mainframe computer?

6. Would you like the input boundary conditions and initial conditions of each code to have built-in default values?

7. Would you like the capability for interactive post-analysis review of the results of any given calculations?

8. What do you guess is the cut-off for P.C.-based simplified analyses, e.g., complex geometries for impact or buckling?

9. How would you be affected if a program took 5 to 10 hours on a P.C. to do its calculation, e.g., for impact or buckling Analysis?

10. Other questions.

REQUIREMENTS DOCUMENT INTERVIEW (Remarks are underlined)

Interviewee: C. Ross Chappell   Date: August 1984

1. To aid in weighting your interview responses with others, indicate the length of time you have been reviewing shipping casks designs.

   /   / 0-1 year   /   / 1-3 years   / X / more than 3 years

   a. What areas of the review process are you primarily involved in? e.g., thermal, structural, load combination?

      Thermal, structural, criticality, and materials.

   b. We understand that casks presented for review usually fall within a set of five generic designs. Based on your experience, do you find this to be the case?

   c. In your experience are there certain conditions that cause critical stresses in a particular type of cask design?

      high thermal stresses in small packages under fire conditions.
      high stresses due to impact.
      large internal pressure under fire conditions.

   d. What is your procedure for reviewing shipping cask designs? Do you have suggestions for a standard procedure for these reviews? (Document each as closely as possible in detail.)

      Project leader assigns one person for each discipline.
      Report reviewed against R.G. 7.9 for format and content.
      Routine calculations include criticality and thermal.
      Structural calculations come mostly from Rourke.
      Burden on applicant for compliance.

Biggest problems-1)completeness, 2) starting assumptions bad, and 3)fudged numbers or bad calculations.

e. What specific methods or computer codes do you use in these confirmatory analyses?

Thermal codes=HEATING6 and HTAS1 from ORNL, post-processing REGPLOT which are part of SCALE (standard compliance analytical tool for licensing evaluation (IBM 370).
Structural tools are quasi-static , e.g. 1)F vs. displ. for impact limiter - provided by user (piecewise linear) and 2) energy comparisons.

f. Is it necessary to use them all for every type of cask design? (e.g., fire condition thermal, thermal stress, oblique impact, buckling) YES

g. What is your procedure for documenting these confirmatory analyses? Do you have suggestions for a standard procedure for documenting these confirmatory analyses?

Series of questions or comments to P.M. and then to licensee who sends in the revised or new data. Then the review process starts again. The documentation package is called the docket and may include the design report (at the discretion of the reviewer). Most of the problems are structural.

h. What format do you use for reporting the results of your review? Do you have suggestions for a standard report format?

NRC wants us to propose some and discuss them. Keep level of data informative, but not thousands of stresses vs. time and location.

i. How do you provide for an audit trail of the information used as input, analytical method, results, et cetera? We would like to provide a standard procedure for defining the audit trail for the review. Do you have suggestions for a standard procedure for this effort?

No formal audit trail procedure now in use. Want to store all PC-based review results on a series of magnetic disks along with the input that was used to generate these results. Only "important" data to be saved, not every stress for every node and time and case.

j. What sources do you use for input information for your analyses?

Oakridge, application, experience and common sense, personal contact with manufacturer by letter or by phone, proceedings from DOE work over the past three years.

k. Do you have a set of reference designs for comparison with a new design?

Not for spent fuel casks.

l. Do you use other groups or subcontractors to assist you with your more difficult calculations?

ORNL for shielding, criticality, and thermal calculations. LLNL, SRI, NOL, BNL, SNLA for computer use and Analysis support.

m. About how long does it take to complete the review of a shipping cask?

/ X / 1-2 year   / X / 2-3 years   / X / more than 3 years

3 years is typical, including 3-4 rounds of questions. Scheduling target is 18 months.

n. Do you know of any plans for change or expansion in the current procedures for reviewing shipping cask designs, i.e., near-term / long-term? Yes, possibly

o. Do you have suggestions for improving the current way of doing things?

More benchmarking of codes and analytical techniques against physical test, especially in the area of inelastic phenomena.
Better definition of allowable strain criteria.

2. What experience do you have with microcomputers? Little
   a. On what machines and with what software? Apple
   b. Do you have access to a microcomputer? None in-house

3. What experience do you have with main frame computers?
   a. On what machines and with what software?
   b. Do you have access to a main frame computer?

   Yes, but don't like to fight JCL

4. How would a coordinated, micro-computer-based system containing codes for calculations necessary to confirm a cask design assist you in your work?

   Automate hand calculations
   Facilitate easy transfer of results between codes
   Provide for automatic load combination calculations and automatic comparison with acceptable values

5. What form do you see as desirable for this system's
   a. program access, e.g., menu-driven, code name, et cetera?

User friendly, error trapped, default values, help package, procedure guidance, input easier to provide than SHOCK code.

b. program input, e.g., interactive question/answer, batch input files?

Interactive the first time, then batch repeats. Want the ability to review the input information and make minor changes easily. This is especially useful since some parametric Analysis must be run with the impact codes and since multiple thermal calculations must be run with only slight changes in the input. Want to avoid having to remember the order of input and the appropriate fields. Have separate geometry and material property files. SUGGEST A WAY, AND WE WILL SEE IF WE LIKE IT!

c. program output, e.g., printed, graphic, screen, parameters?

Want forces, moments, and displacements as well as the stress components, divided into primary and secondary, membrane and bending. Want time histories and profiles as graphical output only. Want peak values as stored and printed values. Want to be able to change level of detail interactively. Want to be able to output all input data, including all available defaults values.

d. comparison with allowable ranges of temperature and stress?

Display intermediate results. User should be able to identify any combination of loads from the results of various calculations.

e. access to changes or updates in the data bases or computer codes?

How do we transmit latest updates-via modem and mailed disk. Each code to have a unique name and developer. Each version to have a unique number on the output results.

f. telecommunication with code developers or a mainframe computer?

Yes, for debugging or for access to 3-D finite element codes.

6. Would you like the input boundary conditions and initial conditions of each code to have built-in default values? YES

7. Would you like the capability for interactive post-analysis review of the results of any given calculations? YES

8. What do you guess is the cut-off for P.C.-based simplified analyses, e.g., complex geometries for impact or buckling?

Structural lumped-parameter calculations

9. How would you be affected if a program took 5 to 10 hours on a P.C. to do its calculation, e.g., for impact or buckling Analysis?

Too long to make multiple runs in one day. Would like better turnaround by using more approximate answer.

10. Other questions

REQUIREMENTS DOCUMENT INTERVIEW (Remarks are underlined)

Interviewee: LLNL project members   Date: mid 1984
expressing their view of what they feel NRC wants

1. To aid in weighting your interview responses with others, indicate the length of time you have been reviewing shipping casks designs.

/__/ 0-1 year   /__/ 1-3 years   /__/ more than 3 years

a. What areas of the review process are you primarily involved in? e.g., thermal, structural, load combination?

Review Group Leader as the project leader with specific persons doing different parts of the review.

b. We understand that casks presented for review usually fall within a set of five generic designs. Based on your experience, do you find this to be the case?

c. In your experience are there certain conditions that cause critical stresses in a particular type of cask design?

d. What is your procedure for reviewing shipping cask designs? Do you have suggestions for a standard procedure for these reviews? (Document each as closely as possible in detail.)

There is not specific procedure available. Reviewers go through applications and present questions to the manufacturers. Do few calculations. Use Reg guides and 10 CFR 71.

e. What specific methods or computer codes do you use in these confirmatory analyses?

f. Is it necessary to use them all for every type of cask design? (e.g., fire condition thermal, thermal stress, oblique impact, buckling)

What do review is based somewhat on previous experience, but no specifics were mentioned.

g. What is your procedure for documenting these confirmatory analyses? Do you have suggestions for a standard procedure for documenting these confirmatory analyses?

Only letters to companies requesting additional information and the applications documents.

h. What format do you use for reporting the results of your review? Do you have suggestions for a standard report format?

See g.

i. How do you provide for an audit trail of the information used as input, analytical method, results, et cetera? We would like to provide a standard procedure for defining the audit trail for the review. Do you have suggestions for a standard procedure for this effort?

j. What sources do you use for input information for your analyses?

k. Do you have a set of reference designs for comparison with a new design?

Just the previous application documents.

l. Do you use other groups or subcontractors to assist you with your more difficult calculations?

BNL, LLNL, LASL, and companies submitting applications

m. About how long does it take to complete the review of a shipping cask?

more than 2 years. No mention of how many at once.

n. Do you know of any plans for change or expansion in the current procedures for reviewing shipping cask designs, i.e., near-term / long-term?

o. Do you have suggestions for improving the current way of doing things?

2. What experience do you have with microcomputers? Little or none
   a. On what machines and with what software?
   b. Do you have access to a microcomputer? No

3. What experience do you have with main frame computers?

   BNL and ORNL, difficult to use

   a. On what machines and with what software? IBM
   b. Do you have access to a main frame computer? ORNL timeshare

4. How would a coordinated, micro-computer-based system containing codes for calculations necessary to confirm a cask design assist you in your work?

   save review time at NRC
   effects time required to get back to company with review results.

5. What form do you see as desirable for this system's

   a. program access, e.g., menu-driven, code name, et cetera?

   b. program input, e.g., interactive question/answer, batch input files, automated checkout of input for reasonableness, built-in default values for input?

   c. program output, e.g., printed, graphic, screen, parameters? FEW

   d. comparison with allowable ranges of temperature and stress?

   e. access to changes or updates in the data bases or computer codes? TELECOM

   f. telecommunication with code developers or a mainframe computer?

6. Would you like the input boundary conditions and initial conditions of each code to have built-in default values?

   Initially the answer was no, but gradually they decided that they wanted to have the capability to see the results before the load combination results were calculated.

7. Would you like the capability for interactive post-analysis review of the results of any given calculations?

8. What do you guess is the cut-off for P.C.-based simplified analyses, e.g., complex geometries for impact or buckling?

9. How would you be affected if a program took 5 to 10 hours on a P.C. to do its calculation, e.g., for impact or buckling Analysis? YES

10. Other questions

APPENDIX B

Interviewee List

LLNL PERSONNEL

1. C. K. Chou (Manager-for review based on previous NRC visits).
2. Les Cover (Project Leader-for review based on previous NRC visits).
3. Ramsey Chun (Developer-for review based on previous NRC visits).
4. Richard Serbin (Developer-for review based on previous NRC visits).
5. Larry Fischer (for a basic understanding of the cask design process).
6. Tom Nelson (Project Leader-opinion subsequent to NRC interview visit).
7. Gary Johnson (Developer-based on previous microcomputer system use experience).
8. Howard Woo (experience in reviewing shipping cask designs at LLNL).

NRC PERSONNEL

1. C. Ross Chappell
2. Gerald Weidenhamer
3. Henry Lee
4. Daniel Huang
5. Earl Easton
6. Herman Graves

(Reviewed by Joe Brandt-Software Engineering Specialist)

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